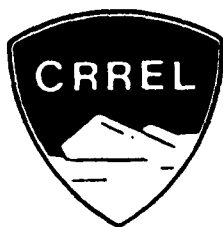


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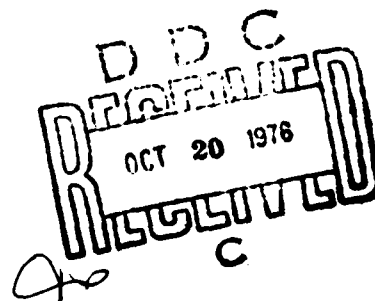
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# THERMAL STRESSES IN A CONCRETE DAM POURED IN SECTIONS

D.P. Levenikh



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HANOVER, NEW HAMPSHIRE

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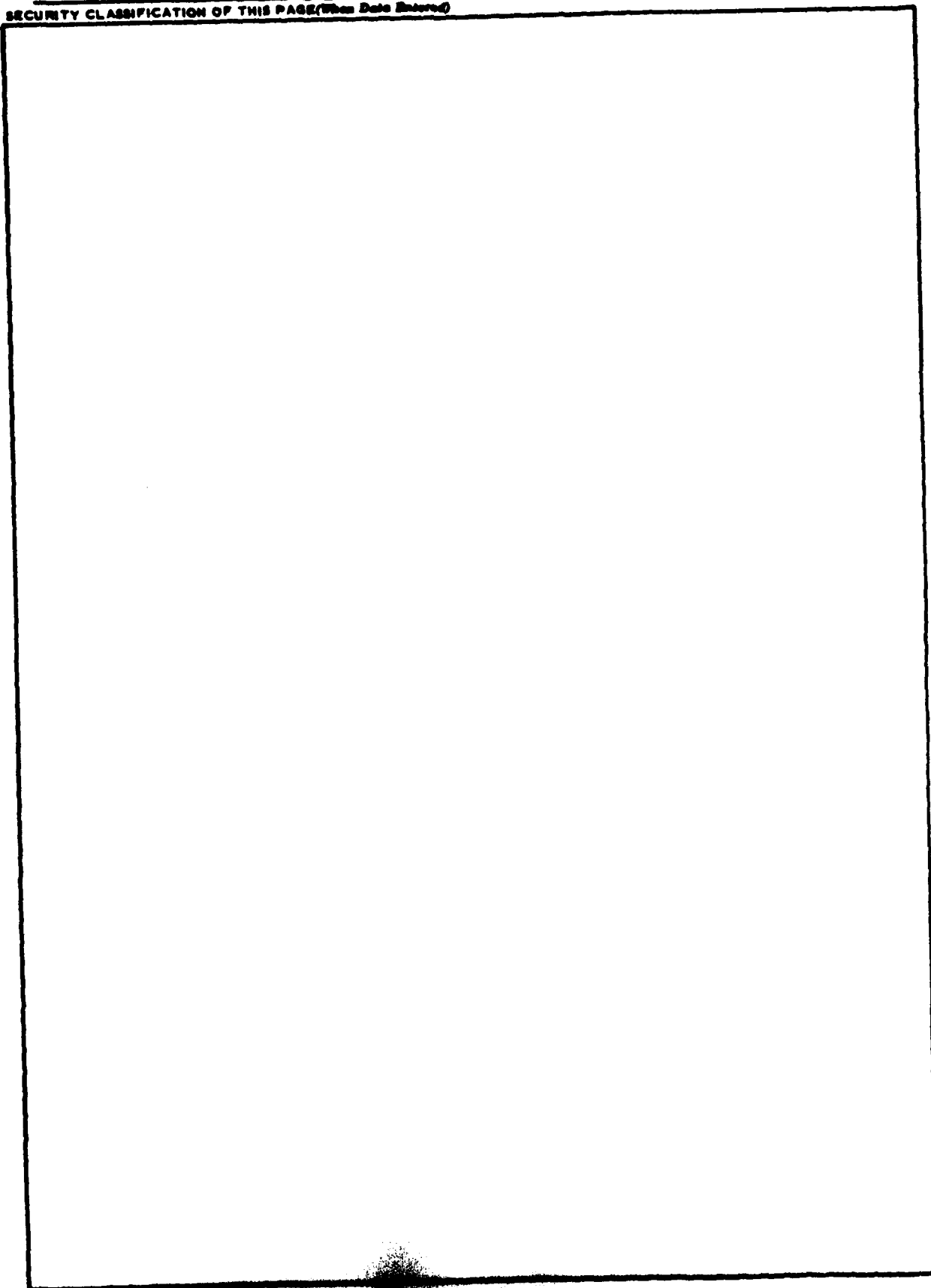
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)  The "mixed-section concrete pouring technique" is described as used in cold regions, and tables are given for selecting optimal thermal conditions for separate operations.		

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## THERMAL STRESSES IN A CONCRETE DAM POURED IN SECTIONS

TRUDY LENGIDROPROYEKTA in Russian No 11, pp 4-24

[Article by D.P. Levenikh]

[Text] When the concrete is poured in sections, the downstream part of a high dam on a rock foundation has a columnar cross section with planned dimensions of the columns of 10-15 m; on the columns are placed long blocks, 0.7-2 m high each, with no lateral vertical joints (Fig. 1). The height of the columnar part of the section may vary within quite a wide range, depending on the shape of the base of the dam, the method used for the concrete work and the construction periods.

It is recommended that the first long block be densely reinforced, making it a so-called reinforced zone, the task of which is to prevent through cracks from developing in the long blocks lying above; the cracks may appear as a continuation of the joints between the columns, resulting from the cooling of the latter.

The sectional pouring was done at the site at several sections of the Krasnoyarsk dam; Planning studies are now being made for the use of long blocks at the Sayanskaya, Ingurskaya, Ust'-Il'mskaya and Zeyskaya dams.

During the construction period of a dam poured in sections, a complex state of thermal stress occurs, and is to a certain extent retained in the period of constant operation. The state of thermal stress of the dam during the construction process is determined by the cooling of the columns, fastened with some flexibility in the rock foundation; the cooling of the long blocks lying on the columns; the cooling of the entire mass of the dam after the joints between the columns are cemented. The process of erecting the dam poured in sections may be divided into five stages (Fig. 2).

At the first stage the columnar part of the section is built; each column is cooled from the volume-average maximal temperature of exothermic heating,  $T_1$ , to a certain temperature,  $T_2$ , independently, and acquires the thermal tension inherent in it.

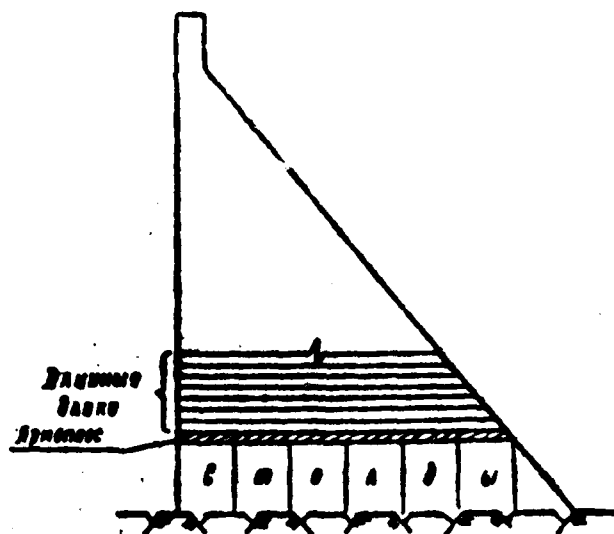


Fig. 1  
Рис. 1. Смешанная разрезка гравитационной плотины на блоки бетонирования.

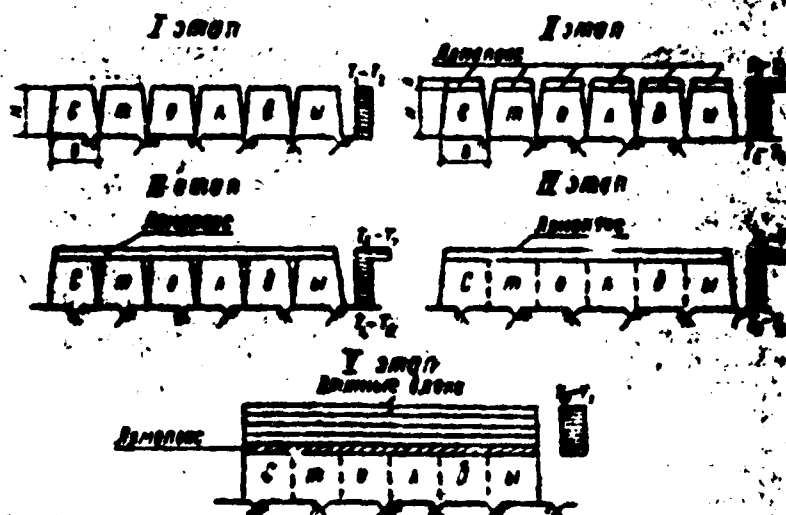


Fig. 2  
Рис. 2. Характерные этапы возведения плотины, имеющей смешанную разрезку.

At the second stage, reinforced frames are placed on the columns and the block of the reinforced zone is concreted; in this case, the tothing is left above the expansion joints in the reinforced zone and the reinforcement in it is not joined; there is further cooling of the columns from  $T_2$  to  $T_4$ , along with the cooling of the reinforced zone from  $T_3$  to  $T_5$ ; each column with the block of the reinforced zone placed on it operates as an independent structure.

At the third stage the reinforcement over the joints is joined and the tothing of the reinforced zone is concreted. The columns cool from  $T_4$  to  $T_6$ , while the reinforced zone cools from  $T_5$  to  $T_7$ ; here the reinforced zone begins to operate in conjunction with the columns as a single structure, resembling a frame with thick supports and zero spans of the horizontal beam.

At the fourth stage the cement grouting of the expansion joints between the columns is carried out, and then the columns cool from  $T_6$  to the long-term average temperature of the concrete masonry,  $T_8$ , while the reinforced zone cools from  $T_7$  to  $T_9$ ; the reinforced zone and the columns operate at this stage as a unified block, fixed in a resilient base.

At the fifth stage the placement of the long blocks continues, and their cooling from  $T_{10}$  to the long-term average temperature  $T_8$  [as published] causes further change in the thermal stressed state of the structure.

The fourth stage may take place in a somewhat different way from that described earlier. Since the cement grouting of the expansion seams requires, to avoid their opening later on, a temperature in the columns quite close to the long-term average temperature of the concrete, the long blocks may be placed above the reinforced structure before the grouting of the expansion joints, and we will have a considerable height of the long-block part of the masonry cooling with the uncemented joints; the fifth stage with this system coincides with that described above.

An approximate method of calculating the thermal stress of the mixed section is presented in [1], but it does not make it possible to ascertain the distribution of the stresses in the reinforced zone above the joints and does not take into consideration the presence of the tothing in the reinforced zone, nor is the fifth stage of the sectioning discussed in it.

An experimental determination of the thermal stressed state of the mixed section was made at the Hydraulic Engineering Laboratory of Leningradskiy inzhenernoy tekhnicheskoy shkoly (LIT) to supplement and elaborate on these studies. The experiments were made using the photoelasticity method on two-dimensional composite models, with equivalent loads in the cold state in a UP-8 laboratory press. The theoretical premises of studying the thermal stress of construction blocks fixed in an elastic base, and the methods of the laboratory study were developed by the laboratory of the OMIN [expansion unknown] VNIIG [All-Union Scientific Research Institute of Hydraulic Engineering imeni V. Ye. Vedeneyev] [3].

We suggested a method of determining the temperature stresses on a series of models obtained consecutively from the same work piece. At all the stages the uniform cooling of the elements of the mixed section were studied with respect to each other. We will discuss determination of the temperature stresses with the simultaneous uniform cooling of the columns and the reinforced zone in relation to the foundation.

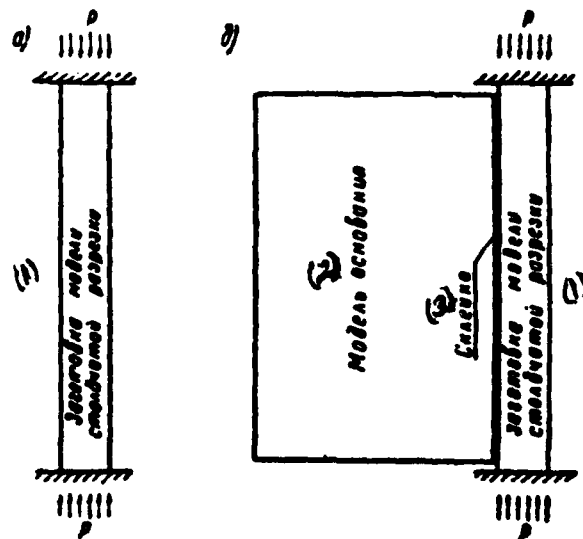


Figure 3. Diagram of Loading and Making the Model

Key:

1. Piece for the model of the column section
2. Model of the foundation
3. Glueing

The work piece for the model of the columns and reinforced zone, which is a parallelepiped made of ED-6 epoxy resin, is compressed in a press with an arbitrary equivalent load of the order of 40-50 kg/cm<sup>2</sup> (Fig. 3, a); after the compressive strain on the block under the load ceases, the model of the base is glued on (Fig. 3, b); after the epoxy glue hardens, the model is relieved of the load and the excess parts of the work piece obtained are removed, as the result of which we have model 1 (Fig. 4), corresponding in its stress to the fourth stage of the mixed section, i.e., to uniform cooling of the structure with the cemented expansion joints for

$$T = \frac{P}{E_0}.$$

where  $E_0$  is the modulus of elasticity of the concrete;  
 $\alpha_0$  is the coefficient of linear expansion for the concrete.

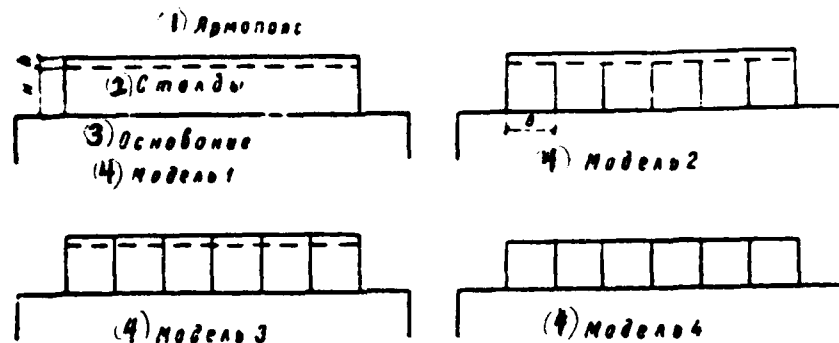


Figure 4. Diagram of a Consecutive Study of the Models of Mixed Section

Key:

1. Reinforced zone
2. Columns
3. Base
4. Model 1, model 2, etc.

It should be noted that with an equivalent compression load we obtain a state of stress corresponding to the heating of the structure; alternation of the stresses determined in studying the model gives us a picture of the cooling. Model 1 turns into model 2, corresponding to the third stage, by making sections in the columnar part of the masonry along the lines of the expansion joints; when the sections are made the stresses in the model change and we obtain the thermal stress of the structure with the combined work of the reinforced zone and the columns and the uncemented expansion joints. Model 2 turns into model 3 by continuing the sections right through to the upper edge of the reinforced zone; model 3 corresponds to the second stage, when the reinforcement above the joints is not welded and the tooth-ing of the reinforced zone is not concreted. Finally, model 3 turns into model 4 after the reinforced zone is removed, which corresponds to the first stage, when the standing columns cool individually.

Studies were made using an analogous scheme of the thermal stress of the section with uniform cooling of the reinforced zone with respect to the columns. The experiments were made for two relations of the width of the column along the foundation to a height of  $B/H=1$ , and  $B/H=2$ , and with the block of the reinforced zone  $h=0.2B$  thick; in addition, experiments were made with the height of the long-block part of the section  $h=0.6B$ , with  $B/H=1$  for the fourth and fifth stages.

L.I. Maslova and V.A. Golubtsov, senior technicians, participated in the experiments.\* All the experiments were made for a mixed section with six columns and for the ratio of the moduli of elasticity of the concrete and the foundation  $E_c/E_0=1$ .

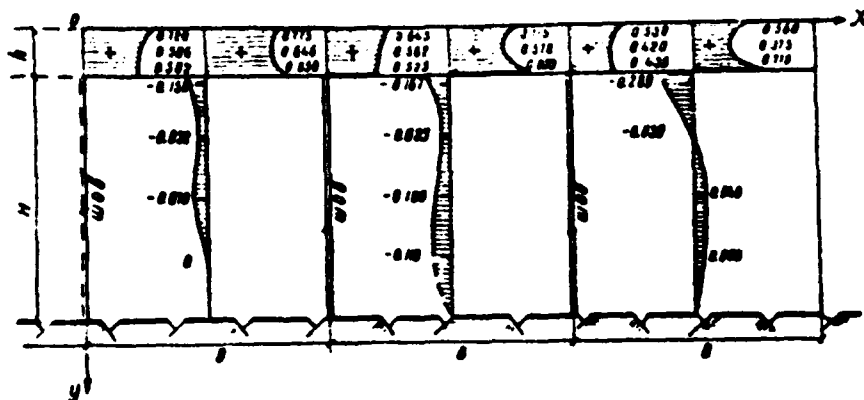


Figure 5. Stresses  $\sigma_x$ , with uniform cooling of reinforced zone relative to columns at  $\Delta T = \frac{1}{E_c}$  for section with  $\frac{B}{H} = 1$  and  $h=0.2B$  (+extension, - compression).

With a large number of columns it is possible, without a significant degree of error, to consider the state of stress of the mixed section in the middle zone as analogous to that for the central columns in the model discussed here. Figure 5 shows the stress sheet  $\sigma_x$ , with uniform cooling of the reinforced zone relative to the columns at the third stage.

The magnitudes of the stresses are given in fractions  $E_c \alpha_r \Delta T$ . To determine the stresses with a given change in the temperature in the reinforced zone  $\Delta T$ , the values of the ordinates of stresses given in the diagram should be multiplied by the formula  $E_c \alpha_r \Delta T$ . Given in tables 1-9 in fractions of  $E_c \alpha_r \Delta T$  are the components of the stresses for all the stages of the mixed section, obtained after studying the above-described models, at the characteristic points designated in Fig. 6. We will illustrate the use of the results obtained from the example of the calculation of stresses  $\sigma_x$  at point 9 of the reinforced zone when  $B/H=1$  and with the temperature regime given in Table 10 for the stages, as well as with the given values  $E=2.9 \cdot 10^5$  kg/cm<sup>2</sup>,  $\alpha_r=10^{-5}$  1/degrees.

At stage 1 there is no reinforced zone. At stages 2, 3 and 4 the columns and reinforced zone cool with respect to the foundation respectively at 5.5 and 2°. In tables 2, 3 and 4 we find the corresponding magnitudes of

\* Similar experiments were made by the method of "freezing" by the laboratory of OMIN VNIIG imeni B.Ye. Vedeneyev in 1963-1964 on the instructions of Lengidproproyekt for the dam of the Krasnoyarskaya GES.

stress  $\sigma_x$  at point 9 in proportions of  $E_s \alpha_s \Delta T$ , equal to 0.098; 0.335 and 0.130. In addition, at stages 2, 3 and 4, the reinforced zone cools with respect to the columns respectively at  $\Delta T_{3-7} - \Delta T_{2-4} = 15 - 5 = 10^\circ$ ;  $\Delta T_{5-7} - \Delta T_{4-6} = 6 - 5 + 1^\circ$  and  $\Delta T_{7-9} - \Delta T_{6-8} = 4 - 2 = 2^\circ$ . In tables 5, 6 and 7 we find the corresponding values of  $\sigma_x$  in proportions of  $E_s \alpha_s \Delta T$ , equal to 0.178, 0.640 and 0.715. Then the resulting stresses  $\sigma_x$  at point 9 at the end of stage 4 will be

$$\sigma_x = 2.9 \times 10^5 \times 10^{-5} \times (-0.098 \times 5 + 0.335 \times 5 + 0.130 \times 2 + 0.178 \times 10 + 0.646 \times 1 + 0.715 \times 2) = 15.4 \text{ kgf/cm}^2.$$

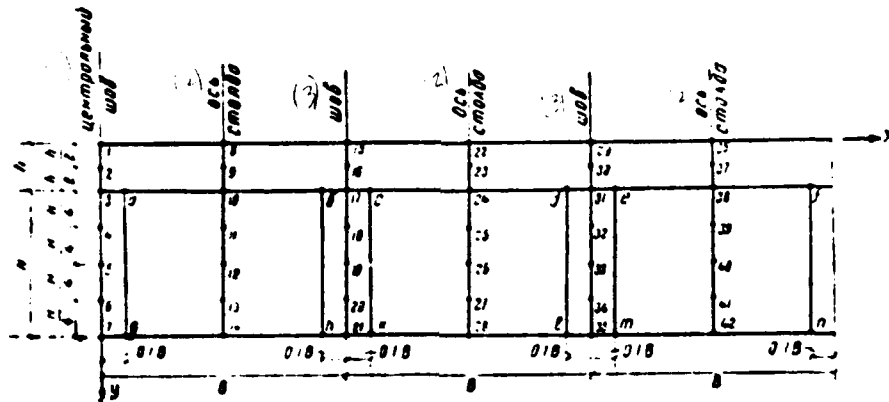


Figure 6. Diagram of the Arrangement of the Calculating Points to Determine the Stress From the Tables

Key:

1. Central joint
2. Axis of column
3. Joint

It must be mentioned that in reality the stresses in the structure will be less due to the phenomenon of creep of the concrete in time. By knowing the calendar periods of the work, this phenomenon may be calculated by multiplying the component stresses for the stages by the corresponding coefficients of relaxation of stress, the magnitude of which depends on the increase in the concrete by the beginning of the stage and on the length of the stage [2]. For a more precise calculation, it is recommended that each of the stages of cooling be developed for several theoretical periods  $\Delta t$  and the stress at each stage be given in the form of the sum of the products of  $\sigma = \sum \sigma_r K_{pr}$ , where  $\sigma_r$  are the stresses arising with a change in the temperature for the period of time  $\Delta t$ ;  $K_{pr}$  is the coefficient of relaxation for the period of time  $\Delta t$ .

Table 1

$\frac{P}{H}$	(1) Напряжения	(2) Номер точки					
		10-24-38	11-25-39	12-26-40	13-27-41	14-28-42	24-29-43
1	$\sigma_x$ . . . . .	0	-0,066	-0,040	0,150	0,610	—
	$\sigma_y$ . . . . .	0	—	—	—	-0,200	0,510
	$\tau_{xy}$ . . . . .	0	0	0	0	0	-0,520
2	$\sigma_x$ . . . . .	-0,137	0,072	0,109	0,350	0,670	—
	$\sigma_y$ . . . . .	0	—	—	—	-0,150	0,403
	$\tau_{xy}$ . . . . .	0	0	0	0	0	0,650

Note: The columns cool uniformly with respect to the foundation. The joints between the columns are uncovered. There is no reinforced zone.

Key:

1. Stress 2. Number of point

Table 2

$\frac{P}{H}$	(1) Напряжения	(2) Номер точки									
		8-22-36	9-23-37	10-24-38	11-25-39	12-26-40	13-27-41	14-28-42	15-29-43	16-30-44	17-31-45
1	$\sigma_x$ . . . . .	-0,133	-0,098	-0,102	-0,070	-0,035	0,075	0,600	—	—	—
	$\sigma_y$ . . . . .	0	—	—	—	—	—	-0,190	0	0,542	—
	$\tau_{xy}$ . . . . .	0	0	0	0	0	0	0	0	0	0,545
2	$\sigma_x$ . . . . .	-0,105	-0,105	-0,046	0,042	0,152	0,320	0,535	—	—	—
	$\sigma_y$ . . . . .	0	—	—	—	—	—	-0,150	0	0,430	—
	$\tau_{xy}$ . . . . .	0	0	0	0	0	0	0	0	0	0,600

Note. The columns and reinforced zone cool uniformly with respect to the foundation. The joints between the columns are uncovered. The tootling of the reinforced zone is not monolithized.

Key:

1. Stress 2. Number of point

Table 3

$\frac{B}{H}$	(2) Номер точки													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0,490	0,460	0,900	0,576	0,335	0,224	-0,040	-0,050	0,075	0,560				
2	0,464	0,298	0,955	0,465	0,350	0,240	0,138	0,106	0,176	0,310				
$\frac{B}{H}$	(2) Номер точки													
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0,450	0,633	0,900	0,530	0,258	0,167	0,080	0,080	0,075	0,585				
2	0,570	0,932	0,830	0,378	0,232	0,182	0,182	0,209	0,238	0,930				
$\frac{B}{H}$	(2) Номер точки													
	29	30	31	32	33	34	35	36	37	38	39	40	41	42
1	0,320	0,496	0,178	0,254	-0,022	-0,022	0,022	0,125	0,150	0,550				
2	0,350	0,017	0,760	0,242	0,003	0,015	0,071	0,113	0,159	0,955				

Table 3 (continued)

$\frac{D}{H}$		(1) Hoop stress	(2) Hoop stress									
			a	10	b	c	24	d	e	38	f	
1	$\sigma_y$ . . . . .	0	0	0	0	0	0,000	0,000	0,002	0,055		
	$\tau_{xy}$ . . . . .	0	0	0	0	0	0	0	0	0		
2	$\sigma_y$ . . . . .	-0,065	0,022	-0,074	-0,074	0,042	-0,069	-0,069	0,016	0,017		
	$\tau_{xy}$ . . . . .	0,246	0,015	-0,219	0,219	0,017	0	0	-0,046	-0,020		

$\frac{D}{H}$		(1) Hoop stress	(2) Hoop stress									
			g	14	h	k	28	i	m	n	o	
1	$\sigma_y$ . . . . .	-	-	-	-	-	-	-	0,300	0,028	0,330	
	$\tau_{xy}$ . . . . .	-	-	-	-	-	-	-	-	-	0,460	
2	$\sigma_y$ . . . . .	-0,107	-	+0,085	-0,085	-	-	0,403	0,403	-0,120	0,374	
	$\tau_{xy}$ . . . . .	0,006	-	-0,650	0,650	-	-	-0,860	0,660	-	-0,540	

Note. The columns and reinforced zone cool uniformly with respect to the foundation. The joints between the columns are uncovered. The tothing of the reinforced zone is monolithized.

Key: 1. Stress 2. Number of point

Table 4

Таблица 4

$\frac{B}{H}$	(I) Номер точки													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0,141	0,151	0,191	0,280	0,360	0,490	0,725	0,119	0,130	0,176	0,265	0,342	0,465	0,682
2	0,286	0,304	0,334	0,375	0,418	0,450	0,900	0,292	0,295	0,322	0,360	0,405	0,433	0,875
$\frac{B}{H}$	(II) Номер точки													
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0,081	0,096	0,134	0,226	0,283	0,373	0,562	0,050	0,059	0,072	0,174	0,260	0,382	0,582
2	0,244	0,262	0,300	0,354	0,414	0,460	0,520	0,238	0,212	0,258	0,312	0,315	0,342	0,932
$\frac{B}{H}$	(III) Номер точки													
	29	30	31	32	33	34	35	36	37	38	39	40	41	42
1	0	0	0	0,100	0,240	0,432	0,682	0	0	0	0,018	0,134	0,378	0,780
2	0,084	0,086	0,149	0,177	0,305	0,428	0,935	0	-0,005	0,007	0,080	0,162	0,376	0,975

Table 4 (continued)

$\frac{P}{W}$	(1) Height in mm	(2) House zone									
		8	14	16	18	20	22	24	26	28	30
1	$\sigma_y$ . . . . .	0	-0,041	-0,100	-0,130	-0,105	0	0,648	0,107	0,450	
	$\sigma_{xy}$ . . . . .	0	-0,012	-0,070	-0,110	-0,111	-0,150	-0,160	-0,282	-0,428	
2	$\sigma_y$ . . . . .	0	0	0	0	0	0	0	0	0,555	
	$\sigma_{xy}$ . . . . .	0	0	0	0	0	0	0	0	-0,424	

Note. The columns and reinforced zone cool uniformly with respect to the foundation. The joints between the columns and the tothing of the reinforced zone are monolithized.

Key: 1. Stress 2. Number of point

Table 5

$\frac{P}{W}$	(1) Height in mm	(2) House zone									
		6-22-46	9-23-37	10-34-38	11-25-39	12-26-40	13-27-41	14-28-42	15-29-43	16-30-44	17-31-45
1	$\sigma_x$ . . . . .	0,343	0,178	0,556 -0,464	0,044	0,020	0	0	0,114	0,238	
	$\sigma_y$ . . . . .	-	-	-0,100	-	-	-	-0,150	+0,213	-0,073	
	$\sigma_{xy}$ . . . . .	0	0	0	0	0	0	0	0	0	
2	$\sigma_x$ . . . . .	0,278	0,206	0,870 -0,130	-0,154	-0,085	0,066	0,074	-	-	
	$\sigma_y$ . . . . .	-	-	-	-	-	-	-0,100	-	0,1,1	
	$\sigma_{xy}$ . . . . .	0	0	0	0	0	0	0	0	+0,075	

Note. The reinforced zone cools uniformly with respect to the columns. The joints between the columns are uncovered. The tothing of the reinforced zone is not monolithized.

Key: 1. Stress 2. Number of point

Table 6

$\frac{B}{H}$	(1) Hopper Tonnage													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0,720	0,596	0,562	0,775	0,646	0,850	0,032	-0,078	0,050	0,057	0,053	0,053	0,053	0,053
2	0,574	0,600	0,730	0,514	0,585	0,710	-0,098	0,050	0,050	0,050	0,050	0,050	0,050	0,050
$\frac{B}{H}$	(1) Hopper Tonnage													
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0,645	0,562	0,525	0,715	0,570	0,833	-0,167	-0,103	-0,023	-0,023	-0,023	-0,023	-0,023	-0,050
2	0,500	0,530	0,635	0,422	0,624	0,656	-0,344	-0,042	-0,097	-0,097	-0,097	-0,097	-0,097	0,053
$\frac{B}{H}$	(1) Hopper Tonnage													
	29	30	31	32	33	34	35	36	37	38	39	40	41	42
1	0,830	0,420	0,435	0,560	0,375	0,715	-0,031	0,045	0,053	0,053	0,053	0,053	0,053	0,053
2	0,386	0,386	0,500	0,202	0,260	0,442	-0,558	0,027	0,018	0,018	0,018	0,018	0,018	0,053

Table 6 (continued)

(1) Hoop stress											
$\frac{p}{H}$											
	a	b	c	d	e	f	g	h	i	j	
	1	0	0	0	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	0	
$\frac{p}{H}$											
	1 <td>0.142</td> <td>—</td> <td>—</td> <td>—</td> <td>—</td> <td>—</td> <td>—</td> <td>—</td> <td>—</td>	0.142	—	—	—	—	—	—	—	—	
	2	0.153	—	—	—	—	—	—	—	—	
(2) Hoop stress											
$\frac{p}{H}$											
	k	l	m	n	o	p	q	r	s	t	
	1	—0.414	—0.261	0.055	—0.268	—0.047	0.230	—0.248	—0.070	0.208	
2	—0.3	—	0.016	—0.180	—	0.024	—0.213	—	0.247		
$\frac{p}{H}$											
	1 <td>—0.078</td> <td>—0.030</td> <td>—0.103</td> <td>—0.066</td> <td>—</td> <td>—0.055</td> <td>—0.106</td> <td>—0.017</td> <td>—0.040</td>	—0.078	—0.030	—0.103	—0.066	—	—0.055	—0.106	—0.017	—0.040	
	2	—0.082	—	—0.072	—0.119	—	—0.058	—0.158	—	—0.018	

Note. The reinforced zone cools uniformly with respect to the columns. The joints between the columns are uncovered. The tothing of the reinforced zone is monolithized.

Key:

1. Number of point

Table 7

(7) Hump TONIN														
$\frac{p}{H}$	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.790	0.785	$\frac{0.820}{-0.180}$	-0.008	-0.098	-0.087	-0.063	0.770	0.715	$\frac{0.830}{-0.170}$	-0.105	-0.085	-0.064	-0.042
2	0.514	0.635	$\frac{0.715}{-0.285}$	-0.144	-0.113	-0.095	-0.077	0.505	0.620	$\frac{0.715}{-0.285}$	-0.156	-0.110	-0.083	-0.061

(1) Hump TONIN														
$\frac{p}{H}$	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0.790	0.720	$\frac{0.830}{-0.170}$	-0.100	-	-	-	0.695	0.700	$\frac{0.800}{-0.200}$	-0.121	0.041	0.053	0.050
2	0.494	0.600	$\frac{0.690}{-0.310}$	-0.180	-0.115	-0.087	-0.067	0.401	0.565	$\frac{0.672}{-0.328}$	-0.187	-0.103	-0.076	-0.050

0.2

Table 7 (continued)

( ) Heavy tons															
$\frac{B}{H}$	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	0.600	0.610	0.730 -0.270	-0.108	-0.118	-0.075	-0.050	0.459	0.450 -0.460	-0.300	—	—	—	—	—
2	0.380	0.404	0.616 -0.384	-0.190	-0.107	-0.080	-0.055	0.133	0.286 -0.426	-0.174	-0.065	-0.005	0.021	—	—

( ) Heavy tons															
$\frac{B}{H}$	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0	-0.039	-0.033	-0.085	0.134	0	-0.007	-0.007	-0.008	-0.022	-0.000	-0.100	-0.102	0.101	—
2	0	0	0	0	0.119	0	0	0	0	0	-0.040	-0.040	-0.021	0.370	—

$\frac{B}{H}$	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	0	-0.635	-0.045	-0.102	-0.244	0	-0.040	-0.040	-0.040	-0.024	-0.031	-0.031	-0.048	-0.048	—
2	0	0	0	0	-0.205	0	0	0	0	0	-0.020	-0.020	-0.040	—	—

Note. The reinforced zone cools uniformly with respect to the columns. The joints between the columns and the tothing of the reinforced zone are monolithized.

Key: 1. Number of point

Table 8

(1) Nonparametric	(2) Histogram													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
$\sigma_x$ . . . . .	0.482	0.398	0.577	0.428	0.301	0.562 -0.438	-0.048	0.055	0.005	0.135				
(1) Nonparametric	(2) Histogram													
	15	16	17	18	19	20	21	22	23	24	25	26	27	28
$\sigma_x$ . . . . .	0.376	0.359	0.518	0.327	0.265	0.517 -0.453	-0.164	-0.093	-0.116	0.100				
(1) Nonparametric	(2) Histogram													
	29	30	31	32	33	34	35	36	37	38	39	40	41	42
$\sigma_x$ . . . . .	0.119	0.300	0.658	0	0.040	0.540 -0.460	-0.164	-0.099	-0.085	-0.070				

Table 8 (continued)

(1) Hinge measure	(2) Hinge tone							
	a	10	b	c	24	d	e	f
$\sigma_y$ . . . . .	-0.031	0.006	-0.064	0.068	-0.047	-0.111	0.084	0.151
$\sigma_{xy}$ . . . . .	0.186	0	-0.083	0	-0.049	-0.147	0	-0.195
(1) Hinge measure	(3) Hinge tone							
	g	14	h	k	28	i	m	n
$\sigma_y$ . . . . .	-0.143	0.005	0.101	-0.099	-0.111	0.182	-0.282	0.571
$\sigma_{xy}$ . . . . .	0	0	0	0	-0.112	0	-0.007	-0.084

Note. The total height of the long blocks and the reinforced zone is  $h=0.6 B$ . The long blocks and the reinforced zone cool uniformly with respect to the columns. The joints between the columns are uncovered and the tooting of the reinforced zone is monolithized.  $\frac{B}{H} = 1$ .

Key: 1. Stress      2. Number of point

Table 9

(1) Hemipennine	(2) H-SEP T-SEP											
	1	2	3	4	5	6	7	8	9	10	11	12
3A	0.173	1.580	0.674 0.326	0.306	0.266	0.211	0.153	0.111	0.500	0.650 0.341	0.291	0.225 0.154
(1) Hemipennine	(2) H-SEP T-SEP											
	13	14	15	16	17	18	19	20	21	22	23	24
3A	0.372	0.171	0.062 0.138	0.530	0.300	0.240	0.221	0.420	0.150	0.614 0.386	0.303	0.250 0.188 0.100
(1) Hemipennine	(2) H-SEP T-SEP											
	25	26	27	28	29	30	31	32	33	34	35	36
3A	0.122	0.280	0.572 0.128	0.329	0.251	0.171	0.125	0.670	0.141	0.313 0.150	0.254	0.101 0.051 0.017

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Table 9 (continued)

(1) Напряжение	(2) Номер точки									
	a	10	b	c	20	d	e	30	f	
$\sigma_y$ . . . . .	0	0	0	0	-0,042	-0,060	-0,060	0,037	0,100	
$\tau_{xy}$ . . . . .	0	0	-0,055	-0,055	-0,093	-0,130	-0,130	0,192	0,222	

(1) Напряжение	(2) Номер точки									
	g	14	h	k	26	i	m	42	n	
$\sigma_y$ . . . . .	0	-0,055	-0,111	-0,111	-0,107	-0,137	-0,137	-0,023	0,032	
$\tau_{xy}$ . . . . .	0	0	0	0	0	-0,029	-0,029	-0,050	-0,058	

Note. The total height of the long blocks and reinforced zone is  $h=0.6 B$ . The long blocks and the reinforced zone cool uniformly with respect to the columns. The joints between the columns and the tothing of the reinforced zone are monolithized.  $\frac{B-1}{H}$

Key: 1. Stress 2. Number of point

Table 10

(1) Элемент конструкции	(2) Номер этапа			
	I	II	III	IV
(3) Столбы . . . .	$\Delta T_{1-2} = 13^\circ$	$\Delta T_{2-4} = 5^\circ$	$\Delta T_{4-6} = 5$	$\Delta T_{6-8} = 2^\circ$
(4) Арматура . . .	—	$\Delta T_{3-5} = 15^\circ$	$\Delta T_{5-7} = 6^\circ$	$\Delta T_{7-9} = 4^\circ$

Key:

- |                       |                    |
|-----------------------|--------------------|
| 1. Structural element | 3. Columns         |
| 2. Number of stage    | 4. Reinforced zone |

Presently used in the construction of high dams in Siberia is pipe cooling of the concrete masonry, cooling the components of the concrete mix, a casing heated in winter, and other measures aimed at reducing the exothermic heating of the concrete, reducing the nonuniformity of cooling the concrete in the blocks in time, the possibility of controlling the temperature of the concrete masonry, and as a result, a guarantee of the monolithic nature and long life of the structures.

When designing concrete dams poured in sections of blocks, this work may be used to select the optimal temperatures, ensuring the monolithic nature of the elements of the section with given criteria for the crack-resistance of the concrete, as well as to select the reinforcement in the reinforced zone.

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